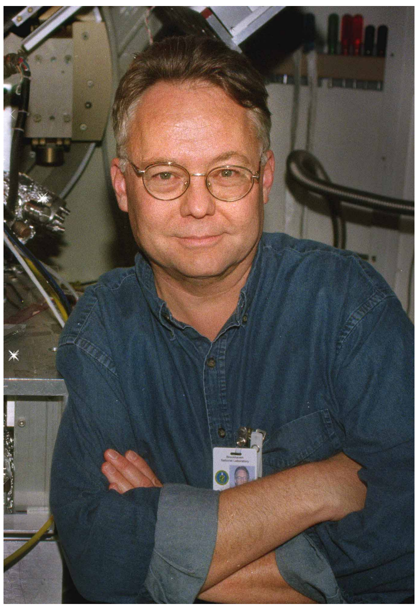
At the NSLS, BNL Scientists Create Stripes, Islands, and Towers

Watching someone align bricks on top of each other to build a wall or a flat surface can get routine. But watching as atoms align themselves like bricks - which can be done by using the intense x-ray light at the NSLS - can lead to seeing intriguing new structures, such as stripes and towers, that may result in improved catalysts, compounds used to accelerate chemical reactions.



Doon Gibbs

The "bricklayers" at the NSLS are BNL physicists Doon Gibbs, Hubert Zajonz and their colleagues. While looking at the properties of bimetallic catalysts - compounds made of two metals that are known to be better catalysts than simple metals are - they were building copper layers, atom by atom, on ruthenium. Suddenly, they noticed that the copper atoms were not simply piling up but had started to make new structures.

At first, they saw that when a single copper layer is deposited, it does not settle as it would in bulk copper. Rather, the atoms adopt the same structure as the ruthenium underneath. "The copper atoms go exactly where the ruthenium atoms would have gone if you were depositing ruthenium instead of copper on the ruthenium surface," Gibbs says.

The surprise came when the scientists added more copper atoms, forming a second layer. This time, the atoms rearranged in domains, each taking one of two possible atomic configurations.

"We found that the atoms switch back and forth in two possible configurations in a regular way," says Gibbs. "We see a periodic distribution of stripes, each stripe corresponding to one configuration or the other."

So the researchers kept adding more copper to see what happens when more layers form on ruthenium.

"We started to see something really bizarre and fun: we started to get islands," Gibbs says.

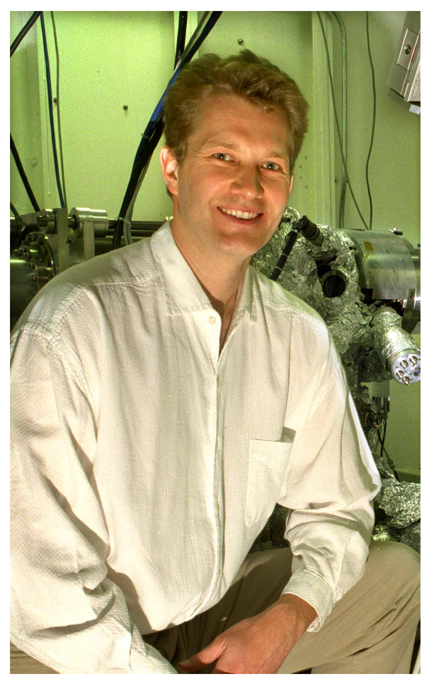
No matter how much copper was deposited on top of the two layers of copper, no new layers formed.

"Little by little, the copper atoms create columns of copper, and, when you add more copper atoms, they run across the surface, jump up on one of the columns, and somehow climb up to the top," Gibbs says. "We end up with a structure in which there is a two-layer film that covers much of the surface, together with these columns of bulk copper sticking up like big buildings."

Gibbs and his colleagues then decided to grow layers of silver instead of copper to see if stripes and towers appeared again. This time, two layers of silver produced more convoluted structures, still with two different configurations.

"Instead of nice stripes following one another, we get little patches of one configuration or the other," Zajonz says. "It may be possible to grow new kinds of nanostructures on these patches, which would change the catalytic properties of the silver-ruthenium compound." The scientists are developing models to understand the origin of such unusual structures. An important parameter is the difference between the interatomic distances in copper or silver and ruthenium.

"The distances between bulk copper atoms is smaller than that between ruthenium atoms," explains Gibbs. "So, when you put a single



Hubert Zajonz

layer of copper onto a ruthenium surface, the distance between the copper atoms is expanded because they are pulled apart. But they want to get closer together, which leads to stripes.

"For silver atoms, it is the opposite," he adds. "The distance between bulk silver atoms is larger than that between ruthenium atoms. So, when you put a single layer of silver on ruthenium, the silver atoms are squeezed and they tend to move apart from each other, creating different kinds of structures."

Gibbs finds the structures "fascinating and beautiful." The scientists are now growing other metals on ruthenium and refining their models for a better understanding of the behavior and catalytic properties of these intriguing structures.

- Patrice Pages

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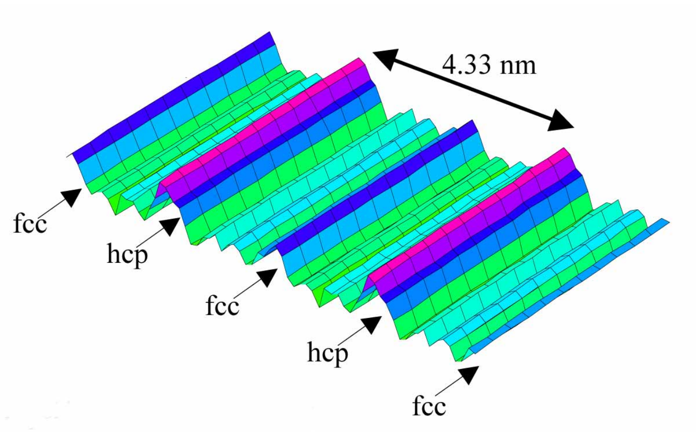

When two layers of copper atoms are deposited on ruthenium, the relative distances between the copper atoms are larger than if they were part of bulk copper. The figure shows the relative strain undergone by the copper atoms, which creates two kinds of structures alternately distributed in parallel with each other to form "stripes." One structure is called hcp (hexagonal close packed) and fcc (face centered cubic).